Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems

Quarterly Technical Progress Report

January 1, 2005 – March 31, 2005

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ABSTRACT

This document summarizes progress on Cooperative Agreement DE-FC26-04NT41992, "Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems," during the time-period January 1, 2005 through March 31, 2005. The objective of this project is to demonstrate at pilot scale the use of solid honeycomb catalysts to promote the oxidation of elemental mercury in the flue gas from coal combustion, and the use of a wet flue gas desulfurization (FGD) system downstream to remove the oxidized mercury at high efficiency. The project is being co-funded by the U.S. DOE National Energy Technology Laboratory, EPRI, Great River Energy (GRE), TXU Generation Company LP, Southern Company, and Duke Energy. URS Group is the prime contractor.

The mercury control process under development uses catalyst materials applied to honeycomb substrates to promote the oxidation of elemental mercury in the flue gas from coal-fired power plants that have wet lime or limestone FGD systems. Oxidized mercury is removed in the wet FGD absorbers and co-precipitates with or adsorbs on byproducts from the FGD system. The current project is testing previously identified catalyst materials at pilot scale and in a commercial form, to provide engineering data for future full-scale designs. The pilot-scale tests will continue for approximately 14 months or longer at each of two sites to provide longer-term catalyst life data.

Pilot-scale wet FGD tests are being conducted periodically at each site to confirm the ability to scrub the catalytically oxidized mercury at high efficiency. The pilot wet FGD system has also been used downstream of catalysts currently being tested as part of another cooperative agreement (DE-FC26-01NT41185).

This is the fifth reporting period for the subject Cooperative Agreement. During this period, project efforts included starting up and operating a catalyst pilot unit at the TXU Generation Company LP Monticello Steam Electric Station, and conducting laboratory catalyst screening tests for the second pilot unit to be installed at Georgia Power's Plant Yates. This Technical Progress Report describes the startup of the oxidation catalyst pilot unit at Monticello and initial elemental mercury oxidation results, and presents results from the laboratory catalyst screening tests.

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INTRODUCTION

This document is the quarterly Technical Progress Report for the project "Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems," for the time-period January 1 through March 31, 2005. The objective of this project is to demonstrate at pilot scale the use of solid honeycomb catalysts to promote the oxidation of elemental mercury in the flue gas from coal combustion, and the use of a wet flue gas desulfurization (FGD) system downstream to remove the oxidized mercury at high efficiency. The project is being co-funded by the U.S. DOE National Energy Technology Laboratory, EPRI, Great River Energy (GRE), TXU Generation Company LP (TXU Generation), Southern Company, and Duke Energy. URS Group is the prime contractor.

The mercury control process under development uses catalyst materials in honeycomb form to promote the oxidation of elemental mercury in the flue gas from coal-fired power plants that have wet lime or limestone FGD systems. Oxidized mercury is removed in the wet FGD absorbers and mostly co-precipitates with and/or adsorbs on the byproducts from the FGD system. The current project is testing previously identified catalyst materials at pilot scale and in a commercial form, to provide engineering data for future full-scale designs. The pilot-scale tests will continue for approximately 14 months or longer at each of two sites, to provide catalyst life data.

Pilot-scale wet FGD tests will be conducted periodically at each site to confirm the ability to scrub the catalytically oxidized mercury at high efficiency. The pilot wet FGD system has also been used downstream of catalysts being tested as part of another cooperative agreement (DE-FC26-01NT41185).

Four utility team members are providing project host sites for mercury oxidation catalyst testing. GRE provided a test site at their Coal Creek Station (CCS), which fires North Dakota lignite, and City Public Service of San Antonio (CPS) is providing a test site at their J.K. Spruce Plant, which fires Powder River Basin (PRB) subbituminous coal. Both the CCS and Spruce mercury oxidation catalyst pilot tests have been conducted as part of project 41185. Both have hosted pilot FGD tests downstream of the catalysts as part of the current, 41992 project.

In the current project, TXU Generation is hosting pilot catalyst tests and intermittent wet FGD pilot tests at their Monticello Steam Electric Station, Unit 3, which fires a Texas lignite/Power River Basin (PRB) coal blend. The TXU Generation test program began during the current quarter, in mid-January.

Duke Energy was also to host oxidation catalyst pilot and wet FGD pilot tests at one of their sites firing low-sulfur Eastern bituminous coal. However, both of their candidate sites (that are having wet FGD retrofitted but not selective catalytic reduction) were measured to have low elemental mercury concentrations in the flue gas downstream of the particulate control device. Consequently, Duke Energy decided not to host oxidation catalyst pilot tests. However, they did host pilot wet FGD tests to determine the ability to scrub the highly oxidized mercury content of the particulate control outlet flue gas at their Marshall Station.

Southern Company has a number of generating units that fire low-sulfur Eastern bituminous coal. They have agreed to host oxidation catalyst tests at their Georgia Power Plant Yates, Unit 1, and to provide project co-funding. Oxidation catalyst pilot tests will commence after the current testing at Spruce Plant is completed, during the second quarter of calendar year 2005.

The remainder of this report presents results from this project for the first quarter of calendar year 2005. The report is divided into five sections: an Executive Summary followed by a section that describes Experimental procedures, then sections for Results and Discussion, Conclusions, and References.

EXECUTIVE SUMMARY

Summary of Progress

The current reporting period, January 1 through March 31, 2005, is the fifth technical progress report period for the project. During the current period, the oxidation catalyst pilot unit that was previously operated at CCS as part of DOE-funded project DE-FC26-01NT41185 was started up at Monticello Unit 3. Three of the four catalysts to be tested at Monticello are currently installed in the pilot unit. Until the fourth planned catalyst, Carbon #6, can be procured, the palladium catalyst previously tested and regenerated at Coal Creek Station is in service in the fourth catalyst chamber. Also during the quarter, the wet FGD pilot unit was shipped from Spruce Plant to Monticello, and set up to treat flue gas from downstream of the catalyst pilot unit. Laboratory testing was conducted to evaluate the performance of candidate catalyst materials at simulated flue gas conditions at Plant Yates, the host site for the second catalyst pilot unit.

Problems Encountered

The most significant problem encountered during the reporting period was a failed (closed) block valve at Monticello that prevented the oxidation catalyst from being started up as soon as the catalysts were installed, on December 1, 2004. The failed valve was opened during a station outage and the oxidation catalyst was started up January 14, 2005.

Since then, there have been minor problems with instrumentation on the catalyst pilot unit. The problems have been with the modem for downloading pilot unit data from the data acquisition computer, sampling valves for the mercury SCEM, solenoid valves that control air flow to the sonic horns on the pilot unit, and both total and differential pressure transducers on the flow measurement venturi for one catalyst box. The modem and sampling valve problems were resolved, but efforts continue to resolve the solenoid valve and differential pressure transducer problems.

Plans for Next Reporting Period

During the next reporting period (April 1 through June 30, 2005), catalysts will be evaluated for elemental mercury oxidation activity at Monticello through routine (~bimonthly) evaluation trips. In April, the wet FGD pilot unit will be operated for two days downstream of each of the four catalysts being tested at Monticello. At the same time, Ontario Hydro measurements will be made at the catalyst pilot unit inlet, catalyst outlet, and FGD outlet to measure relative accuracy for the mercury SCEMs used to quantify catalyst performance and mercury removal across the pilot wet FGD. Other gas characterization measurements will be made, including catalyst inlet halogen, SO_3 and metals concentrations, and catalyst outlet SO_3 concentrations.

The oxidation catalyst pilot tests currently being conducted at Spruce Plant as part of project DE-FC26-01NT41185 will be completed during the next reporting period. That pilot unit will be shipped to Plant Yates and installed there during the quarter.

Prospects for Future Progress

During the subsequent reporting period (July 1 through September 30, 2005), catalysts will be evaluated for elemental mercury oxidation activity at Monticello through routine (~bimonthly) evaluation trips. The oxidation catalyst pilot unit at Plant Yates should be in operation and also be evaluated for elemental mercury oxidation activity through routine evaluation trips. Intensive gas characterization efforts and initial wet FGD pilot testing will likely occur at Plant Yates during the quarter.

EXPERIMENTAL

The work being conducted as part of this project will use three different experimental apparatus types. One is an elemental mercury catalyst oxidation pilot unit (8000 acfm of flue gas treated), the first of which was recently installed at TXU Generation's Monticello Steam Electric Station. A second, nearly identical pilot unit is currently located at CPS' Spruce Plant. During the course of this project, this second pilot unit will be relocated and installed at Georgia Power's Plant Yates.

Each pilot unit has four separate compartments that allow four different catalysts to treat flue gas from downstream of the host plant's particulate control device. Details of the pilot unit design, construction, catalyst preparation and pilot unit operation have been discussed in previous quarterly technical progress reports as part of the ongoing 41185 project[1,2,3,4]. The activity of these catalysts is determined by measuring the change in elemental mercury concentration across each catalyst, while ensuring that the total mercury concentrations do not change significantly across the catalyst. These measurements are primarily conducted using a mercury semi-continuous emissions monitor (SCEM) developed with funding from EPRI. The analyzer has been described in a previous report[5]. Periodically, the analyzer results are verified by conducting manual flue gas sampling efforts in parallel across each catalyst chamber by the Ontario Hydro method.

The second experimental apparatus is a bench-scale test unit that is used to evaluate the activity of candidate catalyst samples under simulated flue gas conditions. The bench-scale catalyst oxidation test apparatus was previously described in quarterly technical progress reports for the 41185 project[3,4].

The third experimental apparatus is a pilot-scale wet FGD unit that is being designed and fabricated as part of the current, 41992 project, to allow the measurement of how effectively catalytically oxidized mercury can be scrubbed. The pilot unit was designed to treat the flue gas from one of four catalyst chambers on either of the mercury oxidation catalyst pilot units. The design basis and a simplified piping and instrumentation diagram (P&ID) for the pilot wet FGD system were included in a previous technical progress report for this project.[6]

RESULTS AND DISCUSSION

This section provides details of technical results available from the current reporting period, January 1 through March 31, 2005. Presented are activity results for the catalyst materials installed in the catalyst pilot unit at Monticello, and results of laboratory catalyst screening tests conducted for candidate catalyst to be tested in the pilot unit that will be moved from Spruce Plant to Plant Yates. Some chemical analysis results from the pilot wet FGD tests conducted at Spruce in the previous quarter are also reported.

Catalyst Pilot Unit Operation at Monticello

The catalyst pilot unit from CCS was shipped to Monticello Steam Electric Station, near Mount Pleasant, Texas, in October 2004. Plant personnel installed the pilot unit adjacent to the 3C ID fan on Unit 3, using 20-in. and 12-in. pipe runs to connect the pilot unit inlet and outlet, respectively, to penetrations made in Unit 3 ductwork during a plant outage in the spring of 2004. The catalysts to be tested at Monticello include Pd #1 catalyst from Johnson Matthey, SCR catalyst from Cormetech/Mitsubishi Heavy Industries, gold from Sud-Chemie Prototech, and Carbon #6 from the usual, unnamed catalyst manufacturer. The first three catalysts were received at the plant during the previous quarter and installed by plant staff. The Carbon #6 catalyst was not yet available, so it was decided to leave the regenerated Pd #1 catalyst from the CCS pilot tests in place, to provide a measure of the activity of a regenerated catalyst over time. The physical characteristics of the four catalysts currently installed are summarized in Table 1.

Table 1. Characteristics of Catalysts Installed in Pilot Unit at Monticello

Catalyst Box Number	Catalyst	Cross Section, in x in (m x m)	Catalyst Depth	Cell Pitch, mm	Cells per Sq. In. (CPSI)	Area Velocity, std. ft/hr
1	Pd #1 (Johnson Matthey)	29.5 x 29.5 (0.75 x 0.75)	9 in. (0.23 m)	3.2	64	52
2	SCR (Cormetech/MHI)	35.4 x 36.2 (0.90 x 0.92)	29.5 in. (0.75 m)	3.3	58	38
3	Gold (Sud-Chemie Prototech)	29.5 x 29.5 (0.75 x 0.75)	3 x 3 in. (3 x 0.08 m)	3.2	64	52
4	Pd #1 (regenerated from CCS)	29.5 x 29.5 (0.75 x 0.75)	3 x 3 in. (3 x 0.08 m)	3.2	64	52

When the plant went to open the valves for flue gas flow to and from the pilot unit on December 1, 2004, a 12-inch butterfly valve on the return line from the pilot unit to the 3C ID fan was found to be stuck closed. After many attempts to force the valve open, it was decided to wait until the next plant outage to remove the valve and open it by direct force to the valve disk rather than just by applying rotational force to the stem. The pilot unit remained off line until a brief

unit outage allowed an opportunity to remove the valve and force it open. The pilot unit was started up on flue gas on January 14, 2005, and operated through the remainder of the quarter.

Catalyst Pressure Drop Performance

In the previous catalyst testing at CCS, fly ash was observed to build up in the horizontal-gas-flow catalyst cells, resulting in increased catalyst pressure drop and lowered catalyst oxidation performance. Sonic horns were installed and were generally effective in preventing fly ash buildup. Since Monticello, like CCS, has an ESP for particulate control (Spruce has a reverse-gas fabric filter), it is expected that the sonic horns will be necessary to prevent fly ash buildup there.

The sonic horns were placed in service on the catalyst pilot unit at the end of January, two weeks after initial startup on January 14, 2005. However, the sonic horns did not operate properly through the remainder of the quarter. During the quarter, a failed compressed air pipe nipple was replaced, the horn timer was replaced, the solenoid valves controlling air flow to the horns were replaced, the horns were disassembled and cleaned, and an air pressure regulator was installed to ensure that the optimum air pressure of 70 psig was supplied to the horns. While these efforts corrected a number of operational issues, it still remains that the solenoid valves controlling air flow to the horns do not turn off properly at the end of their cycle (the horns are intended to sound 30 seconds each every half hour). Currently, the horns sound continuously unless an operator intervenes to momentarily lower the air pressure to the valves, which allows them to close. The new solenoid valves are operating within their design air pressure and solenoid voltage range, so efforts continue to work with the valve manufacturer to troubleshoot why they do not cycle properly.

Two other issues confound the pressure drop data for the oxidation catalysts. One is that the ID fan differential available at Monticello is not as great as at CCS or Spruce, which means that the catalyst pilot only achieves full flue gas flow when Unit 3 is at or near full load. When the unit is at reduced load, the flow rates to the oxidation catalysts also decrease. While this does a good job of simulating the effects of load changes on the oxidation catalysts, it does not allow for extended periods of operation at controlled gas flow rates to observe catalyst pressure drop.

The other issue is that the total pressure and differential pressure transducers for the flow meter for Catalyst 1 (Johnson Matthey Pd #1) did not operate properly when the pilot unit was started up on January 14. At the end of January, the failed components were exchanged with those from Catalyst 4 (regenerated Pd #1 from CCS) since it was thought to be more important to measure and control the flue gas flow rate through the new catalyst rather than the regenerated one. The total pressure transducer was determined to have failed and was replaced, while the differential pressure transducer appeared only to have lost its calibration and was recalibrated. The failed transducer had a delivery time of six weeks, so it was late March before the new and recalibrated components were re-installed.

In spite of these efforts, the flow rate measurement for Catalyst 4 remains inaccurate. It appears that the recalibrated differential pressure transducer still is not operating properly. Consequently, this catalyst box is operated with the control valve manually set wide open. Spot checks on the flow through this catalyst have been made by running “jumper” lines to the transducers for

another box, and indicate that the flow through this catalyst is similar to that across the others (about 1900-2100 acfm at full unit load). However, there remains no accurate measurement or control of flow rate for this catalyst. Efforts continue to troubleshoot this measurement problem.

Figure 1 shows the "full load" pressure drop data for all four catalysts from start up through the end of the quarter. "Full load" was defined as periods where the flue gas flow rate through the highest-flowing catalyst (gold) was at least 1900 acfm. The desired flow rate is 2000 acfm.

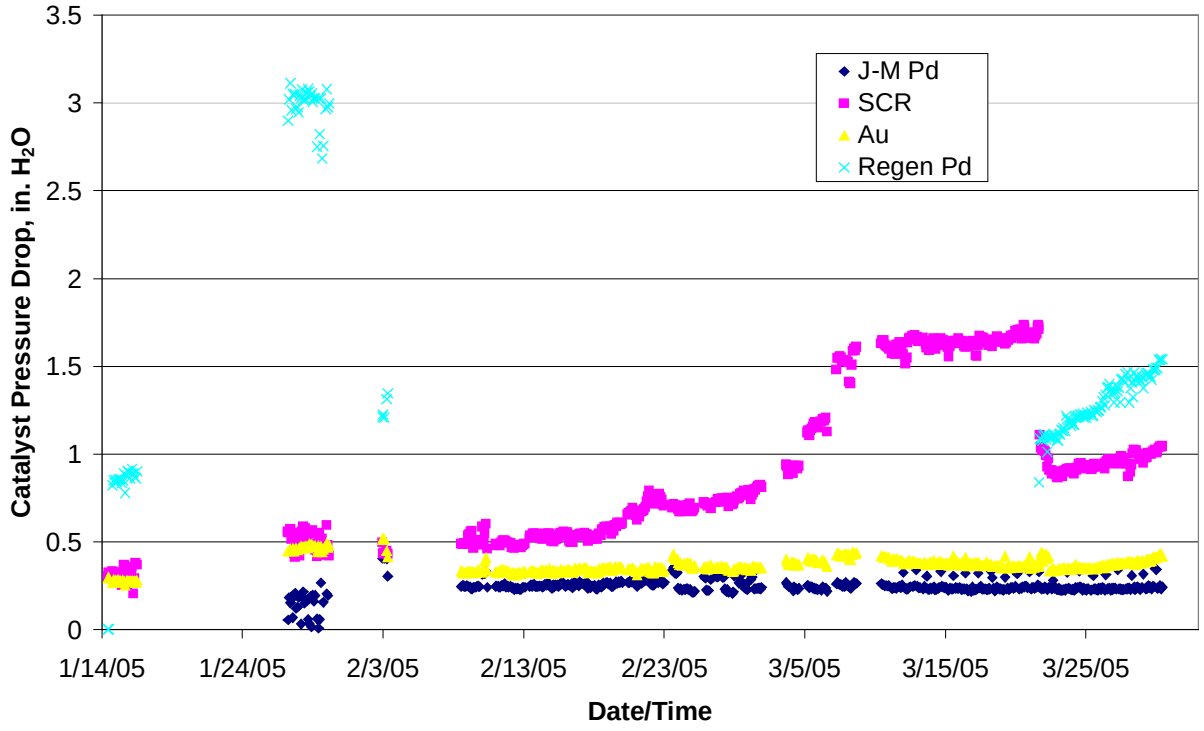

Figure 1. Full-load Catalyst Pressure Drop Data from Monticello Pilot Unit

The data show that the pressure drop across the Johnson-Matthey Pd and gold catalysts remain low (less than 0.5 in. H_2O) while the SCR and regenerated Pd catalysts show excursions to higher pressure drop. Also, due to some common wiring being disconnected, much of the data for the regenerated Pd are missing for the period where the total pressure and differential pressure instrumentation for the flow meter on that box were removed.

The excursions where the pressure drop across the SCR and regenerated Pd catalysts increase appear to correspond with periods where the sonic horns were not operating, related to the issues discussed above. The horns were cycled on March 21 during attempted repairs, and as can be seen in Figure 1, this lowered the pressure drop across the SCR catalyst by over 0.7 in. H_2O.

It is apparent that properly functioning horns will be required to avoid fly ash buildup in the SCR and regenerated Pd catalysts, while the new Pd and gold catalysts are less sensitive to horn operation. It is likely that the SCR catalyst is more sensitive to horn operation because of its greater catalyst length than the others, and that the regenerated Pd is more sensitive because of residual fly ash remaining on the catalyst surfaces from its 20+ months of service at CCS.

Elemental Mercury Activity Performance

The activity of these four catalysts for oxidizing elemental mercury was measured twice during the quarter. The first measurement trip was the week of January 31, approximately two weeks after the pilot unit was placed in service. However, an unscheduled unit outage followed by boiler tuning (with widely variable unit load) made it impractical to try to measure catalyst performance that week. Instead, initial activity measurements were delayed until the following week, February 8-10. The results of measurements made that week are summarized in Table 2.

Table 2. Results of Initial Catalyst Activity Measurements at Monticello, February 8-10

Sample Location	Hg Concentration, $\mu g/Nm^3$ @ 3% O_2				Total Hg % Oxidation		% Hg Adsorption Across Catalyst*	% Hg Oxidation Across Catalyst
	Catalyst Inlet		Catalyst Outlet*					
	Total Hg	Elemental Hg	Total Hg	Elemental Hg	Catalyst Inlet	Catalyst Outlet*		
Measurements on February 8, 2005								
J-M Pd #1	34.9	16.2	2.4	0.48	53	80	93	**
Measurements on February 9, 2005								
SCR	22.2	9.0	3.0	0.14	59	95	87	**
Gold	22.2	9.0	1.9	0.04	59	98	91	**
Regenerated Pd #1	22.2	9.0	1.8	0.04	59	98	92	**
Measurements on February 10, 2005								
Regenerated Pd #1	22.6	-	3.5	-	-	-	85	-
SCR	22.6	-	1.2	-	-	-	95	-
J-M Pd #1	22.6	-	0.85	-	-	-	96	-
Gold	22.6	-	0.65	-	-	-	97	-

*As explained in the text, Catalyst Outlet location values are suspect due to sampling valve malfunctions
**No oxidation percentage is reported because it is not possible to accurately evaluate catalyst performance with high adsorption of mercury apparent across catalyst

These results show high apparent levels of mercury adsorption occurring across the catalysts, which meant it was not possible to quantify elemental mercury oxidation across the catalysts. At high adsorption, it is not possible to distinguish whether it is elemental mercury adsorption or oxidation that accounts for the lowered outlet elemental mercury concentrations.

However, these results showing high levels of mercury adsorption are suspect. The numbers in the table are all reported after being corrected to a 3%-oxygen flue gas basis. The actual oxygen concentrations measured in the sample gas were approximately 7 to 8% at the pilot unit inlet and 11 to 12% at the outlet. While it is possible to correct for air inleakage into the flue gas and/or sample gas based on measured oxygen concentrations, the accuracy of the corrections become questionable when a large correction of 3 to 4 percentage points must be made.

The next sampling trip was conducted one month later, March 8 and 9. At the beginning of this trip, time was spent investigating the high levels of inleakage into the flue gas and/or sample gas across the catalyst pilot unit. The problem was traced to new air-operated solenoid valves used to select which catalyst outlet sample is sent to the inertial gas separator (IGS) filter and on to the sample conditioning impingers in the mercury SCEM. The air pressure to the valves was not adequate to allow the sample valves to fully open, meaning a high vacuum level was established

in the sample gas. This apparently led to high air inleakage into the sample gas. When the air supply pressure to the valve operators was increased, the valves fully opened and the apparent air inleakage across the catalyst pilot unit and/or sample delivery system decreased to only a few tenths of a percent of oxygen concentration. At this point, it is not possible to tell with certainty whether the high mercury adsorption levels seen in February were actually occurring, or represented a measurement error due to the sample valves not being fully opened.

The results of measurements made after the sample valve operator air pressure was increased are summarized in Table 3 below. The results show the gold catalyst to be the most active, with 93% oxidation seen on March 8 when full measurements (total and elemental mercury) were taken, and 91% on March 9 when only elemental mercury concentrations were measured across the catalyst. The palladium was the next most active, with 76% oxidation seen on March 8 but only 66% the following day. The performance of the regenerated palladium was almost identical to the fresh material, with 74% being measured. This lies between the two measurements made for the fresh material. The SCR catalyst was the least active, showing 59% oxidation.

Table 3. Results of Catalyst Activity Measurements at Monticello, March 8-9

Sample Location	Hg Concentration, mg/Nm^3 @ 3% O_2				Total Hg % Oxidation		% Hg Adsorption Across Catalyst	% Hg Oxidation Across Catalyst
	Catalyst Inlet		Catalyst Outlet					
	Total Hg	Elemental Hg	Total Hg	Elemental Hg	Catalyst Inlet	Catalyst Outlet		
Measurements on March 8, 2005								
J-M Pd #1	22.8	10.2	19.1	2.4	55	87	16	76
Gold Outlet	21.3	10.2	19.0	0.7	52	96	11	93
Measurements on March 9, 2005								
J-M Pd #1	-	8.9	-	3.1	-	-	-	66
SCR Outlet	19.0	8.6	17.7	3.5	55	80	6	59
Gold	-	8.9	-	0.8	-	-	-	91
Regenerated Pd #1	18.5	8.9	14.3	2.3	52	84	23	74

However, the performance of the SCR catalyst, and possibly the regenerated palladium, may have been adversely affected by fly ash buildup, as indicated by the pressure drop across these two catalyst beds. This issue was discussed above in this report. The average process conditions during the tests on March 8 and 9 are summarized in Table 4 below.

Table 4. Average Catalyst Conditions During March Activity Measurements

Catalyst	Flue Gas Flow Rate (acfm)	Catalyst Pressure Drop (in. H_2O)	Catalyst Outlet Temperature (^oF)
J-M Pd	1998	0.27	283
SCR	1833	1.62	282
Gold	2055	0.43	293
Regenerated Pd	1915	1.63	287
Catalyst Pilot Inlet	-	-	301

The pilot results for the SCR catalyst and Johnson Matthey Pd #1 from March showed lower oxidation percentages than were expected based on previous laboratory catalyst evaluation

results. Both were expected to achieve approximately 90% elemental mercury oxidation at the area velocities at which they are being operated. The gold catalyst performance was close to what was expected (93% vs. a laboratory value of >95%).

However, recall that these catalysts had been in flue gas service for nearly two months when the field performance values were measured in March, and had perhaps seen some loss of activity. Additional activity measurements will be made across all four catalysts during pilot wet FGD and Ontario Hydro relative accuracy testing in April, and these new results should begin to determine the rate of activity loss versus time for these catalysts.

Also, it should be noted that in previous catalyst testing at Coal Creek Station as part of Cooperative Agreement DE-FC26-01NT41185, an Argillon SCR catalyst showed significantly lower initial activity for elemental mercury oxidation than was expected based on laboratory results.[1] Thus, for an SCR-type catalyst there are previous data which show lower performance in actual flue gas than in simulated flue gas.

Laboratory Screening of Catalysts for Plant Yates

Laboratory evaluation of four candidate catalyst materials at simulated Plant Yates Unit 1 conditions was completed during the quarter. These included palladium catalyst from Johnson Matthey, gold from Sud-Chemie Prototech, SCR catalyst from Mitsubishi Heavy Industries/Cormetech, and Carbon #6 from the usual unidentified supplier. Table 5 shows the laboratory gas species concentrations that were intended to simulate gas conditions at Plant Yates.

Table 5. Target Simulation Gas Composition for Plant Yates Laboratory Tests

Species	Concentration
Hg^0	~50 μg/Nm^3
SO_2	600 ppmv
HCl	10 ppmv
NO_X	200 ppmv
H_2O	6%
CO_2	8%
O_2	8%
N_2	Balance

Table 6 shows the results of tests conducted. All of the results shown are based on the use of KCl solutions in the Hg analyzer impinger train when measuring elemental mercury concentrations downstream of the catalysts. Figure 2 shows a plot of these data, with elemental mercury oxidation percent across the catalyst cores on the Y axis and the effective catalyst area velocity on the X axis. The data show the gold to be the most active catalyst, followed by the SCR catalyst, the Johnson Matthey palladium, and the Carbon #6. Note that the gold was tested at two core lengths, because initial tests with a 1-in. core length produced very high oxidation

percentages. Additional tests were conducted with a shorter, 0.5-in. core length to get performance data at lower oxidation percentages. The two sets of data show relatively good overlap in terms of percent oxidation versus area velocity. The data summarized in Table 6 and plotted in Figure 2 will be used to select and size catalysts for the oxidation catalyst pilot unit at Plant Yates.

Table 6. Laboratory Catalyst Activity Test Results, January Through March 2005

Catalyst	Core Length, in.	Cell Pitch, cpsi	No. of Cells in Core	Flow Rate, L/min	Area Velocity, sft/hr	Hg Concentration ($\mu g/Nm^3$)		Hg^0 Oxidation, %
						Outlet Total	Outlet Hg^0	
Johnson Matthey Pd	0.55	64	14	0.63	54	50.2	6.59	87
Johnson Matthey Pd	0.55	64	14	1.01	86	34.7	6.43	81
Johnson Matthey Pd	0.55	64	14	1.40	119	24.8	5.82	77
Prototech Gold	0.50	64	14	0.63	59	55.49	3.44	94
Prototech Gold	0.50	64	14	1.01	94	36.06	4.46	88
Prototech Gold	0.50	64	14	1.40	131	25.72	5.10	80
Prototech Gold	0.99	64	14	0.63	30	58.1	0.28	>99
Prototech Gold	0.99	64	14	1.01	47	35.4	0.84	98
Prototech Gold	0.99	64	14	1.40	66	26.0	1.31	95
MHI SCR	1.00	47	8	0.63	46	51.8	4.49	91
MHI SCR	1.00	47	8	1.01	73	33.4	3.80	89
MHI SCR	1.00	47	8	1.40	102	25.5	5.34	79
C #6	1.02	77	14	0.63	32	55.5*	6.07	89
C #6	1.02	77	14	1.01	52	34.7*	5.44	84
C #6	1.02	77	14	1.40	72	25.0*	5.82	77

*Because of observed Hg desorption from this catalyst, values in table are inlet Hg^0 concentrations

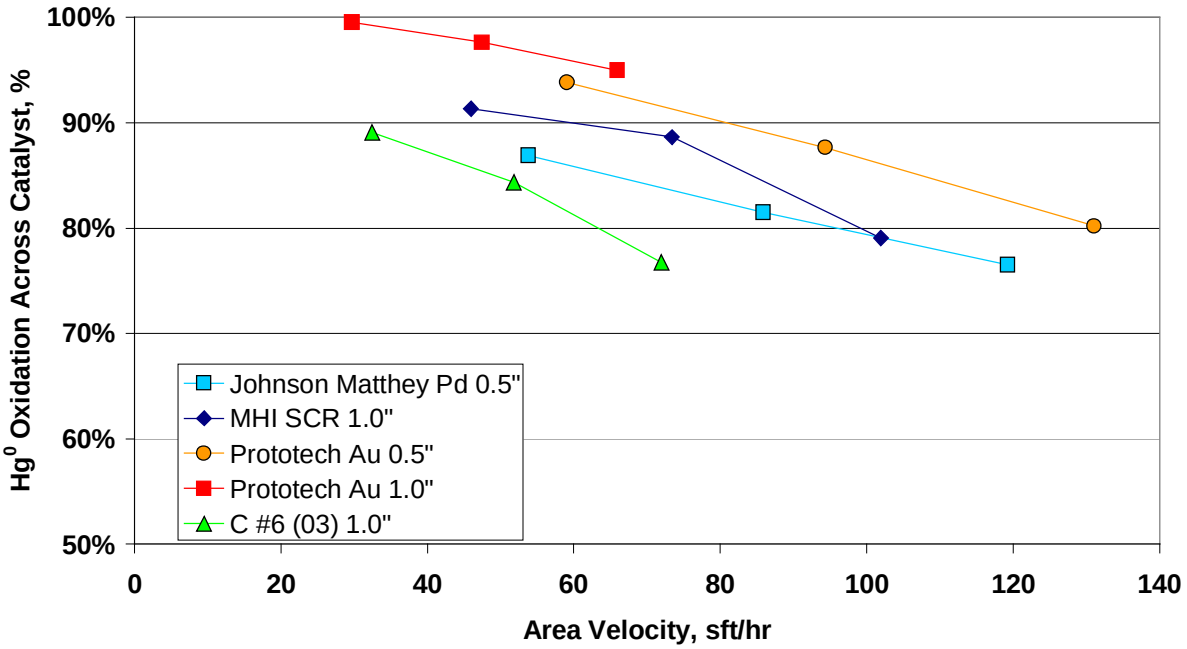

Figure 2. Catalyst Hg^0 Oxidation Activity Results from the Current Quarter at Simulated Plant Yates Gas Conditions

Pilot Wet FGD Tests at Spruce Plant

Pilot wet FGD tests were conducted at Spruce plant in October and November 2004. Spruce Plant fires Powder River Basin (PRB) coal and has a reverse gas fabric filter for particulate control followed by a limestone natural oxidation wet FGD system.

As described in a previous Technical Progress Report, the pilot wet FGD system is sized to treat all of the flue gas exiting a single catalyst compartment from the mercury oxidation catalyst pilot unit.[6] Over the last two weeks in October and continuing into the first week of November, 2004, the pilot wet FGD system was operated for a series of day shift tests (about 10-12 hours each) downstream of each catalyst compartment, with separate tests being conducted with lime and limestone reagents. Both reagent types are used in wet FGD systems installed on plants that fire PRB coal. One baseline limestone test was also conducted.

Lime reagent tests were conducted using dry high-calcium hydrated lime powder from the Austin White Lime Company slurried in plant water in the pilot wet FGD reagent tank, while the limestone tests were conducted using the Spruce full-scale FGD reagent. Lime reagent tests were conducted in a natural sulfite oxidation mode, while the limestone reagent tests were conducted in a forced oxidation mode, with FGD liquor sulfite concentrations being controlled below 1 mmol/l (80 mg/l).

For each reagent type, the FGD reaction tank was not drained between tests. Instead, each test was begun with the FGD slurry remaining from the previous test in the reaction tank. It was felt that this would be better than starting each day with fresh slurry, as the previous days' slurry liquor should have been near steady state with respect to concentrations of chlorides, mercury,

and other dissolved species. Most other potentially important parameters (e.g., pH, sulfite concentration) would reach steady state values soon after startup each day, and would depend on the reagent makeup and pilot unit control parameters. However, the reaction tank inventory was changed when making the transition from lime to limestone reagent. For both reagent types, the pilot wet FGD reaction tank was originally charged with recycle slurry from one of the Spruce full-scale wet FGD module reaction tanks (limestone, high natural oxidation).

Wet FGD tests were conducted downstream of all four catalysts at Spruce, including the palladium-based (Pd #1), carbon-based (C #6), gold, and SCR catalysts. A baseline (no catalyst) test was also conducted by withdrawing flue gas from the 20-in. inlet duct to the oxidation catalyst pilot unit through a 10-in. port installed by Spruce Plant personnel.

Mercury removal results for this test were reported in the previous Technical Progress Report for this project.[7] Samples of the FGD liquors and solids were periodically collected during these pilot wet FGD tests, and were analyzed for typical FGD species and mercury concentrations. These chemical analyses were completed during the current quarter and are reported in Tables 7 and 8 below.

Table 7. Summary of FGD Liquor Analyses from Pilot Wet FGD Tests at Spruce Plant

Date	Catalyst	Ca^{++}, mg/L	Mg^{++}, mg/L	Na^{+}, mg/L	Cl^{-}, mg/L	$CO_3^{=}$, mg/L	$SO_3^{=}$, mg/L	$SO_4^{=}$, mg/L	Hg, µg/L
Lime Reagent Tests									
10/20/04	Gold	742	1,717	5,078	7,247	240	0	7,167	NA*
10/21/04	C #6	755	1,326	4,117	5,763	149	0	6,085	NA
10/22/04	SCR	746	1,460	4,146	5,990	197	0	5,890	14.4
Limestone Reagent Tests									
10/26/04	Gold	747	2,868	8,306	11,644	63	4	11,153	33.0
10/27/04	Pd #1	730	2,645	7,224	10,442	44	3	10,326	NA
10/29/04	C #6	754	2,366	6,854	9,813	38	3	9,276	9.2

*NA – no analysis

Table 8. Summary of FGD Solids Analyses from Pilot Wet FGD Tests at Spruce Plant

Date	Catalyst	Inerts, wt% of total solids	Solids, wt% in slurry	Ca, mg/g	Mg, mg/g	SO_3, mg/g	SO_4, mg/g	CO_3, mg/g	Hg, µg/g	Oxidation, %	Reagent Utilization, %
Lime Reagent Tests											
10/20/04	Gold	2.44	6.35	217	0	0	518	2	NA*	100	99
10/21/04	C #6	2.07	6.85	224	0	0	522	2	NA	100	97
10/22/04	SCR	1.94	7.11	221	0	0	518	2	1.55	100	97
Limestone Reagent Tests											
10/26/04	Gold	3.26	6.83	224	0	0	509	7	3.32	100	94
10/27/04	Pd #1	2.49	9.06	221	0	0	517	2	NA	100	97
10/29/04	C #6	2.92	6.67	218	0	0	510	7	2.45	100	97

*NA – no analysis

The results show that there was not much difference between the lime and limestone test chemistries. Concentrations of highly soluble species (Mg, Na and Cl) were higher during the limestone tests, suggesting that liquor concentrations cycled higher during the limestone tests. However, this may have just been a function of how concentrated or dilute the full-scale absorber liquor was running at the time absorber recycle slurry was taken to fill the pilot FGD system reaction tank. The pilot FGD reaction tank was filled separately at the beginning of the lime tests and at the beginning of the limestone tests.

Both the lime and limestone test results showed complete sulfite oxidation, which is common under low-sulfur-coal FGD conditions. Also, the observed reagent utilization was high for both reagent types, ranging from 94 to 97% for the limestone tests and 97 to 99% for the lime tests.

The liquor and solids mercury analysis results were used to calculate the percentage of mercury in the slurry in the solids versus that in the liquid phase. In all three sample sets, the mercury was predominantly in the solid phase (88 to 95%). Because these tests were generally only one day in duration each, the relatively long solids residence time in the reaction tank, and because the reaction tank slurry was not changed from day to day, it was not possible to use these analytical data along with gas-phase data to calculate a mercury balance around the pilot unit.

CONCLUSION

Initial catalyst activity test results show that gold is the most active of the four catalysts being tested at the Monticello Station, followed by palladium (new and regenerated) then the SCR catalyst. Neither the SCR nor the Johnson Matthey (new) palladium catalyst are as active as was predicted from laboratory catalyst screening test results based on field measurements made in March. However, the SCR catalyst results may be adversely affected by fly ash buildup within the catalyst. It is apparent that reliable operation of the sonic horns will be necessary to keep the SCR catalyst and also the regenerated palladium catalyst clean. For the gold and Johnson Matthey (new) palladium catalysts, it does not appear that optimum sonic horn operation is as critical.

The results of laboratory catalyst screening tests predict that gold will be the most active catalyst for the Plant Yates flue gas conditions, followed by the MHI SCR catalyst, Johnson Matthey palladium, and Carbon #6. These laboratory activity data will be used to select and size catalysts for the oxidation catalyst pilot unit at Plant Yates, and will be compared to the pilot catalyst data as they become available.

The analytical results from pilot wet FGD operation downstream of the catalysts at Spruce Plant show that the mercury removed by the wet FGD was predominantly found in the FGD solids (88 to 95% of the total mercury in the slurry), regardless of the reagent and oxidation mode. However, it should be noted that in both the lime natural oxidation and limestone forced oxidation tests, the FGD liquor and solid sulfites were observed to be completed oxidized.

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